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2014

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### ***citation for published version (APA)***

Kuik, O. J. (2014). *International competitiveness and leakage: A case study of the European steel industry*. Institute of Environmental Studies, VU University Amsterdam. <http://cecilia2050.eu/publications/272>

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**Choosing Efficient Combinations of Policy Instruments for Low-carbon development and Innovation to Achieve Europe's 2050 climate targets**

# International competitiveness and leakage

A case study of the European steel industry

Deliverable 5.2





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Project coordination and editing provided by Ecologic Institute.

Manuscript completed in [December,2014]

This document is available on the Internet at: [optional]

**Document title** International competitiveness and leakage

**Work Package** WP5

**Document Type**

**Date** 10 December 2014

**Document Status**

## ACKNOWLEDGEMENT & DISCLAIMER

The research leading to these results has received funding from the European Union FP7 ENV.2012.6.1-4: Exploiting the full potential of economic instruments to achieve the EU's key greenhouse gas emissions reductions targets for 2020 and 2050 under the grant agreement n° 308680.

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## LIST OF ABBREVIATIONS

BF	Blast furnace
BOF	Basic oxygen furnace
CDM	Clean development mechanism
CGE	Computable General Equilibrium (model)
CO	Carbon monoxide
CO <sub>2</sub> (-eq)	Carbon dioxide (equivalent)
CLL	Carbon Leakage List
DG Clima	European Commission Directorate-General for Climate Action
EAF	Electric arc furnace
EITE	Energy-intensive and trade-exposed (sectors)
EU	European Union
EU ETS	European Union's Emissions Trading Scheme
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GHG	Greenhouse Gas
Gt	Giga tonnes (= 10 <sup>12</sup> kg)
JI	Joint Implementation
KC	Capital-Knowledge (model of FDI and the multinational firm)
Mt	Million tonnes (= 10 <sup>9</sup> kg)
O <sub>2</sub>	Oxygen
OECD	Organisation of Economic Co-operation and Development
OLI	Ownership, Location, and Internalization
RCA	Revealed comparative advantage
RTB	Relative trade balance
SIC	Standard of Industrial Classification






## 1 Executive summary

In this study an analytical framework is developed for explaining how international investment patterns might be influenced by climate policy and applied this to the European steel industry as a case study. The analytical framework is based on recent literature on the relationships between competitiveness, international investment, and environmental stringency. For the case study, a CGE model was used to develop feasible scenarios of the evolution of competitiveness of the European steel industry and carbon leakage for alternative instrument mixes and alternative levels of global participation in climate change policies.

The question whether environmental policies affect industrial competitiveness and lead to the international relocation of pollution-intensive firms and/or production capacity has been extensively studied in the contexts of the Pollution Haven hypothesis and the Porter hypothesis. The Pollution Haven effect is the effect, on the margin, of a tightening up of pollution regulation in one region on plant location decisions and trade flows in the direction of other regions. The Pollution Haven effect is contested by the Porter Hypothesis. The basic idea proposed by Porter is that properly crafted stringent regulation can actually produce greater innovation and innovation offsets than lax regulation since it requires more fundamental solutions than end-of-pipe ones. Despite three decades of research there is no full consensus on the validity of these hypotheses. On the Porter Hypothesis, recent empirical studies have found a positive relationship between environmental policy and innovation, suggesting some support for the weak version of the Porter Hypothesis. As to the strong version of the Porter Hypothesis, a recent OECD review of the literature suggests tentatively that researchers who studied the link between environmental policy and competitiveness (expressed as trade flows and location decisions) at the sector and national level *tend to conclude* that environmental regulation has a negative impact on competitiveness. Likewise, recent empirical literature tends to find evidence for the Pollution Haven effect.

In the long term, competitiveness is determined by international investment patterns, for example in the form of Foreign Direct Investments (FDI). The nature of these flows has long been a bit of a puzzle in standard neo-classical theory. On the basis of theoretical developments in trade theory ('new trade theory') and contract theory, important innovations have been made in the theory of the multinational enterprise and FDI. On the basis of this new theory, an empirical study suggested that the relationship between environmental stringency of the host country and inward FDI can be depicted by an inverted U curve. A decrease in environmental stringency in the host country will have a positive impact on the amount of FDI up to a limit or threshold after which the impact will become negative. The idea is that if environmental stringency is too low, investors may interpret this as a signal of poor regulatory quality that poses a risk for their investments. Hence, the relationship between environmental stringency and FDI would be non-linear.




A practical way to look at the relationship between environmental regulation and industry location is the ‘evidence-drivers’ framework developed by Ecofys. ‘Evidence’ for international relocation of production is found in changes in net imports and investment activity. An important driver of production relocation is worldwide developments in demand. Depending on the sector, distinctions can be made between market segments, e.g. high quality and low quality steel, where proximity is usually more important for the high quality end of the market. Prices and availability of raw materials and energy can be important drivers of relocation, as can be wages and availability of qualified labour. For example for steel, the prices and availability of iron ore, coking coal, and scrap are important drivers, as is the price of electricity. World market prices of important inputs can be distorted in countries where state aid and subsidies are still in place. Trade and investment agreements can be a driver of relocation in complex ways. Especially in the past, (high) import tariffs were sometimes seen as a motivation for FDI. Carbon costs can also be a driver. Carbon costs can be direct and indirect and they should be weighed against abatement options. Also important is the ability of an industry to pass-on the costs to its customers.

Considering all evidence and drivers together should make it easier to assess the relative importance of climate policy on the production relocation of specific sectors. The ‘evidence-drivers’ framework allows for a mixed qualitative-quantitative assessment.

Steel production is a carbon-intensive activity. For the production of one ton of steel in Europe, on average 1.3 tons of CO<sub>2</sub> are emitted to the atmosphere. The EU steel industry emits about 120 thousand tons of CO<sub>2</sub> annually and is thus responsible for more than 20% of emissions of manufacturing industry and construction in Europe. The energy and carbon intensity of steelmaking decreased considerably in the 1980s and 1990s, when obsolete technologies of steelmaking (e.g., ‘Open Heart’ furnaces) were abolished, more metal scrap was recycled, and the process of ‘casting’, i.e., the casting or moulding of liquid steel into certain shapes, dimensions and weights, became more energy-efficient with the introduction of the continuous-casting process. Steel is produced in a large number of varieties for a large number of end-uses. Major end-uses are construction, the car industry, mechanical engineering, and metal goods. Steel is an essential input for many renewable energy supply technologies such as (offshore) wind mills and other renewables such as geothermal, hydro, and biomass.

In the context of the EU ETS, the steel industry was well-endowed with free emissions allowances throughout the first and second trading period. It has been estimated that for every year under the EU ETS, the allocation of free allowances exceeded the verified emissions in the steel sector. Thus far, no carbon leakage from the European steel industry has been observed, perhaps partly due to the generous allocation of free allowances. The development of the EU ETS post 2020 is not entirely clear yet. The 2013 Green Paper that has the objective to consult stakeholders on the development of the 2030 framework, briefly addresses competitiveness issues. It discusses electricity prices that have increased over the last decade and that are likely to increase further towards 2030. It proposes a number of options to address the negative impacts of energy costs on the competitiveness of the EU



economy. Intermediate reports from a public consultation suggest that there is broad support for more funding for innovation, and that there is a call, especially from industry, to base the allocation of allowances on more recent production volumes, and to take account of indirect cost increases because of increasing electricity prices.

In order to get more insights into feasible scenarios of the evolution of competitiveness of the European steel industry and carbon leakage for alternative instrument mixes and alternative levels of global participation in climate change policies, a number of simulations were run with the recursively-dynamic CGE model GDyn that has an innovative approach to international investment. The main conclusions from the simulations are that without any safeguards to the industry, and in the event of moderate climate ambitions in the rest of the world, an ambitious climate policy in Europe could lead to a significant loss of competitiveness of the steel sector and a high and increasing rate of carbon leakage. An increasing part of the carbon leakage is due to changes in international investment patterns. This so-called ‘investment leakage’ would be responsible for 60% of carbon leakage in 2050.

Granting free carbon allowances to the energy-intensive and trade-exposed industries in an *output-based* fashion after 2020 and compensating them for increased electricity prices, would, according to the analysis, mitigate fears of loss of competitiveness and reduce, but not eliminate, carbon leakage.

Fears of loss of competitiveness and risk of carbon leakage would disappear if countries were to agree on coordinated ambitious action to tackle climate change. In such a Global Coordination scenario there would be no carbon leakage per definition and our simulations suggest that the competitiveness of the European steel industry might increase in the long term.

## 2 Introduction

### 2.1 Background

In the short to medium-term, international competitiveness and carbon leakage are affected by the effects of climate policies on the supply costs of vulnerable industries in relation to their competitors abroad. International competitiveness is defined as an industry's ability to maintain profits and market share, carbon leakage as the increase in emissions outside a region as a direct result of climate policies in that region. Deliverable 2.8 of the CECILIA2050 project (Kuik et al., 2013) addressed short-term carbon leakage. Carbon leakage occurs through two main channels: the competitiveness channel and the international fossil fuel price channel. The root of the competitiveness channel is that the cost of compliance gives a comparative disadvantage for regulated firms vis-à-vis their competitors abroad. The change of relative costs can lead to a change of the trade balance: less exports and more imports. In the short term, this would correspond to a change of the utilisation rate of existing capacities (operational leakage), while in the long term, it would correspond to a change in production capacities (investment leakage). These changes induce a shift of production, and then of emissions, from the regulated part of the world to the unregulated part of the world. In the long run, international competitiveness and carbon leakage are mainly determined by international investment patterns that are driven by differences in supply costs and many other factors, including numerous market and policy imperfections. In order to design appropriate policy instruments to mitigate carbon leakage and to support the international competitiveness of vulnerable industries it is vital to understand the drivers of international investments and especially the relation between international investment and environmental stringency.

### 2.2 Statement of purpose and contents of the report

This task in the framework of the EU FP7 project CECILIA2050 developed an analytical framework for explaining how international investment patterns might be influenced by climate policy and applied this to the European steel industry as a case study. The analytical framework is based on recent literature on the relationships between competitiveness, international investment, and environmental stringency. For the case study, literature and statistical data were collected and analysed. Stakeholders were consulted. A CGE model was used to develop feasible scenarios of the evolution of competitiveness and leakage for alternative instrument mixes and alternative levels of global participation in climate change policies.

Following this introduction, the report is structured as follows: Chapter 3 reviews the general literature on environmental regulation and industry location. Chapter 4 presents an economic model of foreign direct investment and discusses a study that uses this model to

statistically assess the effect of environmental regulation on foreign direct investment. Chapter 5 introduces the European steel sector as a case study, while Chapter 6 reports on a CGE analysis of feasible scenarios of the evolution of competitiveness and carbon leakage for alternative instrument mixes and alternative levels of global participation in climate change policies. The report closes with conclusions in Chapter 7 and a list of references. The following overview describes how the tasks outlined in the project's Description of Work have been implemented.

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**Sub-task 5.2.1 outline in the Description of Work      How the tasks have been implemented**

<p>This sub-task will develop an analytical framework for explaining international investment patterns and apply this to selected industries, such as aluminium and steel.</p>	<p>An economic model of foreign direct investment is presented in Section 4.1. Elements of the 'evidence-drivers' framework for production relocation is applied to the steel sector in a case study.</p>
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<p>The analytical framework will be based on recent literature on the relationship between investment and environmental stringency.</p>	<p>The relationship between investment and environmental stringency is described in Section 4.2, based on recent literature.</p>
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<p>For the case studies, we will collect and analyse statistical data and industry forecasts, and consult with industry analysts and representatives both within and outside of the EU. We will also use elements of the techno-economic scenario development in WP3.1.</p>	<p>The case study is introduced in Chapter 5, that discusses techno-economic characteristics of the European steel industry, the policy context, and options and opinions from industry stakeholders. Elements from the techno-economic scenario development in WP3.1 are used in the CGE analysis</p>
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<p>The case studies will present feasible scenarios of the evolution of competitiveness and leakage for alternative instrument mixes and alternative levels of global participation in climate change policies.</p>	<p>A full CGE analysis of feasible scenarios of the evolution of competitiveness and leakage for alternative instrument mixes and alternative levels of global participation in climate change policies was carried out.</p>
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## 3 Environmental regulation and industry location

### 3.1 Introduction


The question whether environmental policies affect industrial competitiveness and lead to the international relocation of pollution-intensive firms and/or production capacity has been studied in the contexts of the Pollution Haven Hypothesis and the Porter Hypothesis.

The Pollution Haven Hypothesis was originally framed because of concerns about the environmental impacts of the liberalization of international trade (Brunnermeier and Levinson, 2004). The Pollution Haven Hypothesis posits that a reduction of trade barriers will lead to a shift of polluting industries from countries with stringent environmental regulations to countries where these regulations are weaker. It is furthermore quite well possible that governments deliberately lower their environmental regulations to attract overseas firms. Copeland and Taylor (2004) assert that a distinction should be made between the Pollution Haven Hypothesis and the Pollution Haven *Effect*. While the former (the ‘Hypothesis’) primarily refers to the effects of a reduction of trade barriers, the latter (the ‘Effect’) refers to the effects of a tightening of pollution regulation. In this report, the Pollution Haven Effect is the central concept. Copeland and Taylor (2004: 9) define the Pollution Haven Effect as the effect, on the margin, of a tightening up of pollution regulation on plant location decisions and trade flows.

Porter (1990) and Porter and van der Linde (1995) contested the Pollution Haven Hypothesis. The basic idea proposed by Porter is that properly crafted stringent regulation can actually produce greater innovation and innovation offsets than lax regulation since it requires more fundamental solutions than end-of-pipe ones. While the cost of compliance may rise with stringency, the potential for innovation offset may rise even faster. Thus, the net cost of compliance can fall with stringency and may even turn into a net benefit that can lead to absolute advantage over firms in foreign countries not subjected to similar regulations (Porter and van der Linde, 1995).

#### 3.1.1 The Pollution Haven Effect

The early empirical literature on the Pollution Haven Effect suggested that environmental regulations had little effect on industry location decisions (e.g., Jaffe et al., 1995). The common explanation was that the costs of compliance with these regulations were usually too small in comparison to other costs. Later it has been suggested that the results might also have been due to a number of statistical problems (Brunnermeier and Levinson, 2004). In the first place, the older studies were based on cross-section data that did not control for attributes of countries or industries that correlate with environmental stringency and economic strength. For example, if a country has a comparative advantage in the production of a polluting good, it will export the good, it will generate a lot of pollution, and (all else being equal) impose strict regulations to reduce the pollution. A cross-section comparison



may find that export success and environmental stringency are positively correlated and the researcher may interpret this erroneously as evidence supporting the Porter Hypothesis. In the second place, the older studies do not address the issue that environmental stringency may itself be influenced by international trade. That this is not just a theoretical curiosity has been suggested by Busse and Silberberger (2013) who found that an increase of net exports of pollution-intensive goods lowered environmental stringency in a panel of 92 countries over the period 1998-2007.

Recent empirical studies correct for unobserved heterogeneity and endogeneity of the regulatory stringency variable and find statically significant evidence for the Pollution Haven Effect. Brunnermeier and Levinson (2004) classify the econometric studies with respect to the dependent variable they wish to explain: location, output, or input (capital or labour). Due to a lack of comparable cross-country data, the studies that have directly assessed the effect of environmental stringency on location decisions have primarily focussed on interjurisdictional competition for the siting of new plants between US counties. The studies that focus on output measure the effect of regulatory stringency on patterns of specialization and trade among countries. Finally, studies that focus on inputs, test whether regulatory stringency affects the movement of inputs, such as capital in the form of foreign direct investment (FDI), across regions.

Recent studies that study locational decisions within the US use panel data to account for unobserved heterogeneity and find evidence of the Pollution Haven Effect. They focus on air quality regulation. Under this regulation, counties are subject to national ambient air quality standards. Firms in counties that failed to attain the standards face stricter regulations than firms in attainment areas. Henderson (1996) found that counties that meet a particular standard for a number of years see a significant increase in the number of polluting plants. In contrast, Becker and Henderson (2000) estimated that nonattainment status reduced the number of new plants belonging to heavily polluting industries by 26% to 45% during the 1963-1992 period. Rutqvist (2009) finds no evidence for the Pollution Haven Effect on the US *State* level, except for a small effect on the iron and steel industry.

Looking at output variables, for example changes in net imports, Ederington and Minier (2003) and Levinson and Taylor (2008) find that abatement costs have a significant effect on net imports for US polluting industries. The most extensive study to date is by Broner et al. (2012) who examined the revealed comparative advantage with respect to pollution of more than 70 countries in 80 industries who export to the US. They find that countries with lax environmental regulations in air pollution systematically display higher US import market shares in polluting industries. This finding is confirmed and even strengthened when they use an instrument for the stringency of environmental regulation to avoid the endogeneity problem that we referred to earlier.

In this report, we are most interested in studies that look at input variables, particularly capital. Greenstone (2002) conducted a panel data analysis at the manufacturing plant level in the US and found that counties that were in nonattainment of national ambient air quality



standards lost about 590,000 jobs and USD 37 billion in capital stock between 1972 and 1987. Keller and Levinson (2002) also used panel data on incoming FDI in the US and found that pollution abatement costs had a small but significant negative effect on new foreign investment projects. In contrast, Hanna (2010) examined the relation between US environmental regulation and the outflow of FDI by US-based multinational firms. Again using air quality policy as the environmental driver, Hanna (2010) estimates that over the period 1966-1999 US air quality policies induced regulated multinational firms to increase their foreign assets by 5% in polluting industries. This outflow of capital is however small in relation to the stock of the multinationals' domestic assets in polluting industries (approximately 0.6%). Sanna-Randaccio and Sestina (2011) argue that a firm's decision to relocate in response to tighter environmental regulation also depends on relative market sizes between the source and the target countries. More generally, a good statistical model to explain the effect of environmental regulation on FDI should be based on a good theoretical model of FDI. We will discuss such a model later and we will discuss one study that uses this model for a statistical analysis of environmental stringency and FDI.


Most of the studies above carry out their analysis at the level of aggregated pollution-intensive industries and are not concerned with sector detail. Alfaro and Charlton (2009) argue that research on has sometimes led to the wrong conclusions on the motives for FDI because it was based on a too high sectoral aggregation level. Specifically, examining FDI strategies of firms at the four-digit Standard of Industrial Classification (SIC) level reveal a greater importance of factor-cost based factors than examining those firms at the two-digit level where demand factors seem to dominate. A number of studies point to sector differences in their extent of 'footlooseness', i.e. their relative ability to migrate. Ederington et al. (2003) argue that most polluting industries are the least mobile and less likely to migrate because of existing external economies of scale and high transportation and plant-level fixed costs. Van Beers and van den Bergh (1997) also reached a similar conclusion.

### 3.1.2 The Porter Hypothesis

The Porter hypothesis has also been extensively tested. Early evidence in its support (for example offered by Porter himself (1991)) is based on a small number of case studies at the firm level that cannot be easily generalized (Lanoie et al., 2008). Jaffe and Palmer (1997) characterized this evidence as anecdotal.

Tests of the Porter Hypothesis generally fall into three categories: testing the weak version, testing the strong version at the firm-level and testing the strong version at the national/sector-level (Ambec et al., 2013).

The weak version of the Porter Hypothesis states that properly crafted environmental policy may spur innovation. It is usually assessed by measuring the expenditures in Research & Development (R&D) or the number of successful patent applications. Jaffe and Palmer (1997) estimated the relationship between pollution abatement costs and R&D expenditures and patents and they found a statically significant positive link for the R&D expenditures but not for the number of patents. In a review study, Ambec et al. (2013) report that many studies



have found a positive relationship between successful patent application and the stringency of the environmental policy. Ambec et al (2013), Lanoie et al. (2008) and OECD (2010) agree that empirical studies have found a positive relationship between environmental policy and innovation, although the strength of the relationship varies across the studies.

The strong version of the Porter Hypothesis at the firm level asserts that the innovation induced by environmental regulation more than offsets any additional regulatory costs and therefore enhances the competitiveness of the firm. Many of the empirical studies focus on the effect of environmental regulation on productivity. Productivity is considered a key element in competitiveness. The main conclusion from this body of research has been that the nature of the relationship cannot be determined with certainty (OECD, 2010). In a review of the literature, Ambec et al. (2013) concluded that a common flaw in empirical studies is that the firm's productivity is tested without having in consideration any other cause for the variation in business performance. Another criticism is that most of the studies do not properly address for the dynamic nature of the Porter Hypothesis.

Assessing competitiveness between nations is directly linked to the original hypothesis that environmental regulation may enhance a country's competitiveness. A common way to empirically assess the linkage is by analysing the Pollution Haven Effect (see above). According to OECD (2010), researchers who studied the link between environmental policy and competitiveness (expressed as trade flows and location decisions) at the sector and national level tend to conclude that environmental regulation has a negative impact on competitiveness, thereby rejecting this version of the Porter Hypothesis

## **4 Foreign direct investment and environmental regulation**

### **4.1 A model of foreign direct investment**

A common critique of empirical studies that test the Pollution Haven or Porter Hypothesis is that the statistical models are not well specified. Brunnermeier and Levinson (2004) argue in their review of empirical studies on the effect of environmental regulation on industry location that studies that do a poor job of predicting the signs of control variables should be viewed with suspicion. Sanna-Randaccio and Sestina (2011) argue that firm location studies should take relative market sizes into account, but this is only one of the elements of a more complete theory of FDI, as we will show below.

Foreign direct investment (FDI) is the category of international investment that reflects the objective of a resident entity in one economy obtaining a lasting interest in an enterprise resident in another economy.<sup>1</sup> FDI has long been a puzzle in neo-classical trade theory.<sup>2</sup>

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<sup>1</sup> For a complete glossary of terms related to Foreign Direct Investment, see <http://www.oecd.org/investment/investmentfordevelopment/2487495.pdf> (accessed 19/11/2014).

Traditional theory made little distinction between FDI and international portfolio investment flows. In traditional theory, multinational firms were arbitrageurs that moved capital from countries where returns were low to countries where returns were high. Hymer (1960) was the first to make a fundamental distinction between FDI and portfolio investment, using an industrial-organization approach. He recognized that portfolio investment, based on different interest rates, does not explain the element of control that is a characteristic of FDI. He assumed that multinational firms own special assets that confer a competitive advantage over foreign firms. If market imperfections preclude the use of these assets by foreign firms, it generates a need for a direct involvement by the asset owner. After a number of refinements in the literature, Dunning (1981) formulated his now classical eclectic OLI framework to explain FDI and the multinational enterprise, where OLI is acronym for Ownership, Location, and Internalization. Ownership advantage refers to the firm-specific asset that a firm must have to go international; Location advantage makes it efficient to exploit the firm asset in multiple countries; and Internalization advantage makes within-firm exploitation of that asset dominate exploitation at arm's-length (hence the 'control' element in FDI). It took the development of new trade theory (Krugman, 1980; Helpman and Krugman, 1985) and contract theory (Dixit and Stiglitz, 1977) to formalize Dunning's conjecture. Early contributions to a complete theory were provided by Markusen (1984) and Helpman (1984). A model of FDI and the multinational enterprise that is frequently used for empirical research is the 'Knowledge-Capital model' (Markusen and Maskus, 2002). The Knowledge-Capital (KC) model and especially its empirical specification by Carr et al. (2001), has been called the "workhorse for analyzing international investment flows." (Kalamova and Johnstone, 2011: 13). The main problem that the KC model has 'solved' is to explain in one model two types of FDI: 1) the horizontal type, where a multinational firm produces in multiple countries to minimise trade and firm-specific fixed-costs, and 2) the vertical type, where firms geographically fragment production by stages, by, for example, doing labour-intensive stages of production in countries with relatively cheap labour.

The KC model starts with three assumptions (Carr et al. 2001):

1. Services of knowledge-based and knowledge-generating activities, such as R&D, can be geographically separated from production and supplied at low cost.
2. The knowledge-intensive activities are skilled-labour-intensive relative to production.
3. Knowledge-based services have a joint-input characteristic, in that they can be utilized simultaneously by multiple production facilities.

The first two assumptions explain the motivation for 'vertical' fragmentation, where firms geographically fragment production by stages. The headquarter that produces knowledge capital is located in the parent country where skilled labour is abundant, while production can be located in the country where unskilled labour is abundant (and wages are lower). The last assumption explains 'horizontal' fragmentation, where firms produce the same goods

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<sup>2</sup> The history of FDI theory is based on an overview paper by Antràs and Yeaple (2013) on multinational firms and the structure of international trade.

and services in multiple countries. Because of the high trade costs (of natural or man-made origin) it may be profitable to set-up affiliate production facilities to avoid the trade costs, i.e. to 'jump the tariff fence'. From these three assumptions, a model can be built that can make predictions about FDI on the basis of (relative) country size, skilled labour endowment, and trade costs. Because of the joint-input characteristic of knowledge capital, there are economies of scale in production. Headquarter services (blueprints, manuals, formulas, procedures, etc.) can be supplied to multiple plants at low cost.

The KC model explains the volume of production of foreign affiliates and hence FDI of one country's firm in another country as a function of the characteristics of both the parent country and the host country. The headquarter of the multinational is in the parent country and the foreign affiliate is in the host country. The actual KC model consist of 41 non-linear inequalities that can be numerically solved. We will not describe this model in detail, but we will only discuss a number of its features and its empirical specification for estimation purposes.

The KC model predicts that affiliate production and FDI will be high if the countries are similar in size and transport costs are high (horizontal FDI). Affiliate production and FDI will also be high when the parent country is both skilled-labour abundant and small relative to the host country (vertical FDI). The comparative statics of the KC model are interactive and non-linear. For example, an increase in trade costs will increase production by affiliates if the countries are similar (horizontal FDI) but may decrease production if the countries differ in relative skilled-labour endowment (vertical FDI). The effect of an increase of the parent's country GDP on FDI is non-monotonic. It increases when the parent country is small, but decreases if the size of the parent country exceeds the size of the host country. The effect of an increase in the parent country's endowment of skilled labour on FDI is large if trade costs are small (vertical FDI is encouraged), but smaller if trade costs are large. Table 1 shows the basic empirical specification of the KC model, with explanatory variables, their expected signs and a brief explanation. Some of the non-linearities of the KC model are captured in the interaction terms (e.g. GDP difference x Skill difference).

**Table 1 Basic empirical KC model**

Variable	Expected sign	Explanation
Sum of GDP	+	Sum of the sizes of parent and host country encourage FDI because of economies of scale (joint input characteristic of knowledge capital)
GDP difference squared	-	Differences in size discourage FDI
Skill difference	+	Skill differences encourage vertical FDI
GDP difference x Skill difference	-	Interaction between size difference and skill difference. FDI is highest when parent country size is small (GDP difference is negative) and skill-labour-abundant is large (skill difference is positive)

Cost of investing in host country	–	The cost of investing in the host country is also dependent upon regulatory quality and cultural differences
Cost of exporting to host country	+	Trade costs encourage horizontal FDI
Trade cost x Skill difference squared	–	Interaction between trade cost and skill difference squared. The interaction term captures the fact that trade costs may encourage horizontal FDI but discourage vertical FDI and vertical FDI is dominant when skill differences are large
Cost of exporting back to parent country	–	High trade costs discourage vertical FDI

Source: constructed on the basis of Carr et al. (2001).

Kalamova and Johnstone (2011) have used the KC model to empirically estimate the relationship between environmental stringency and FDI for a sample of 27 OECD parent countries and 99 host countries over the period 2001-2007. They hypothesised that the relationship between environmental stringency of the host country and inward FDI could be depicted by an inverted U curve. A decrease in environmental stringency in the host country will have a positive impact on the amount of FDI up to a limit or threshold after which the impact will become negative. The idea is that if environmental stringency is too low, investors may interpret this as a signal of poor regulatory quality that poses a risk for their investments. The hypothesis is graphically shown in

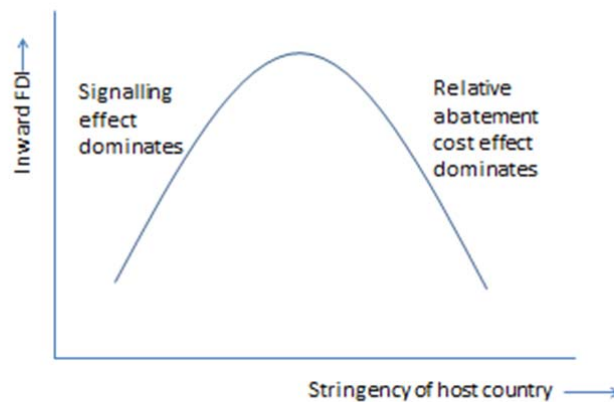


Figure 1 Relationship between environmental stringency of the host country and inward FDI

Source: Kalamova and Johnstone (2011)

Kalamova and Johnstone (2011) adjusted the empirical specification of the model shown in Table 1 in a few ways. The most important adjustments are the introduction of a variable of environmental stringency difference between the parent and host countries and its square. The other adjustments are more of a technical nature and are less important here. Kalamova and Johnstone use the environmental stringency index of the World Economic Forum for their environmental stringency variable. This is a subjective index, based on perceptions of representatives (often CEOs) of between 8,000 and 10,000 firms worldwide. Kalamova and Johnstone (2011) argue that finding an objective measure for stringency is near impossible given the heterogeneity of policy regimes both across countries and within countries across sectors and impacts as well as through time. Besides, perceptions are an important factor in firm's location strategies. The square of the environmental stringency difference variable is used to test the existence of a threshold.

Kalamova and Johnstone (2011) estimated a number of models: with data of the whole sample, data restricted to FDI from OECD to non-OECD countries, and data of FDI flows within OECD countries only. The best model is the second model that explains FDI from OECD to non-OECD countries. Except for one interaction term all explanatory variables have the right sign and are significant. The negative coefficient of the squared environmental stringency difference term confirms the inverted U relationship between environmental stringency and FDI. The model that explains within-OECD FDI also finds a clear positive impact of the environmental stringency difference, suggesting that the Pollution Haven Effect also occurs within the OECD.

**Table 2 Estimation results for KC 'environmental stringency and FDI' model**

Variable	Whole sample	OECD to non OECD	OECD only
Sum of GDP	6.52E-13***	1.34E-12***	1.07E-13
GDP difference squared	-2.93E-26***	-4.25E-26**	-2.18E-26***
Interaction term I	-3.15E-18	-8.28E-18***	-1.53E-18
Interaction term II	1.81E-18	9.39E-18***	5.64E-19
Interaction term III	2.48E-18	-5.45E-17	2.26E-18
Distance	-0.0002292***	-0.0002916***	-0.0001842***
Customs Union	0.6894951***	0.6155521**	1.224973***
Free trade agreement	0.4805627***	0.6560606***	0.7275514**
Common border	1.412304***	2.778845***	1.440371***
Common language	1.121314***	2.230499***	0.4175423

Regulatory quality	0.5393671**	0.7347263**	0.3073314
Stringency difference	-0.0189284	0.3414885**	0.0666871
Stringency difference squared	0.0336551**	-0.0824404***	0.0496366*
Observations	9711	5071	4640
Uncensored observations	5822	2673	3149
(Pseudo) R-squared	0.17	0.21	0.12

Notes: \*\*\*-significant at 1% level, \*\*-significant at 5% level, \*-significant at 10% level; the dependent variable is the natural logarithm of FDI; all columns present Tobit estimates that include year, parent and host country fixed effects; Interaction term I is  $\Delta\text{Skill} \times \Delta\text{GDP}$  if  $\Delta\text{Skill} > 0$ , and 0 otherwise, this term is expected to be negative for vertical FDI and have no effect on horizontal FDI; Interaction term II is  $\Delta\text{Skill} \times \Sigma\text{GDP}$  if  $\Delta\text{Skill} > 0$ , and 0 otherwise, this term is expected to be positive for vertical FDI and negative for horizontal FDI; Interaction term III is  $-\Delta\text{Skill} \times \Sigma\text{GDP}$  if  $\Delta\text{Skill} < 0$ , and 0 otherwise, this term is expected to be negative for all modes of FDI; the terms Common Language, Common Border, Customs Union, Free Trade Agreement are dummy variables that represent trade costs; Regulatory quality is a measure for cost of investing in the host country.

Source: Kalamova and Johnstone (2011)

## 4.2 Environmental regulation and foreign direct investment

A recent study for the European Commission in preparation of the 2030 framework assessed evidence of carbon leakage for a number of selected sectors. The study developed a framework for assessing changes in competitiveness, or more specifically in 'relocation'. The study uses the terms 'Drivers for (production) relocation' for determinants and 'Evidence for (production) relocation' for consequences. Table 3 shows the aspects of evidence (consequences) and drivers (determinants) and that are being distinguished.

**Table 3 Evidence and drivers of relocation**

Evidence for production relocation	Drivers for production relocation
Net imports	Carbon cost
Net indirect imports	Abatement options compared to carbon cost
Investment activity in EU compared to outside EU	Other costs: raw materials
	Other costs: energy inputs
	Other costs: labour

	Other costs: electricity
	Pass through of costs
	World demand
	Transport costs
	Trade & investment agreements

Source: Ecorys et al. (2013)



Evidence for the international relocation of production is potentially found in changes in net imports and international investment activity. The study distinguishes between net imports and net indirect imports. Indirect imports refers to consumption or intermediate goods that contain the good or commodity of interest. For example for the commodity steel, net indirect imports refer to goods that contain steel, such as cars, ships, machines, white goods and so on (Molajoni and Szewczyk, 2012). Investment activity can be measured in money but also in physical production capacity, e.g. 'million tons of steelmaking capacity'.

An important driver of production relocation is worldwide developments in demand. Depending on the sector, distinctions can be made between market segments, e.g. high quality and low quality steel, where proximity is usually more important for the high quality end of the market. Prices and availability of raw materials and energy can be important drivers of relocation, as can be wages and availability of qualified labour. For example for steel, the prices and availability of iron ore, coking coal, and scrap are important drivers, as is the price of electricity. World market prices of important inputs can be distorted in countries where state aid and subsidies are still in place (Ecorys et al., 2013). Trade and investment agreements can be a driver of relocation in complex ways. As we noted in Section 4.1, high import tariffs can be a motivation for 'horizontal' FDI, because by setting up a production facility in the import-protected country a company could 'jump the tariff fence', but they would discourage 'vertical' FDI.


Finally then, carbon costs can be a driver. Carbon costs can be direct and indirect and they should be weighed against abatement options. Also important is the ability of an industry to pass-on the costs to its customers.

Considering all evidence and drivers together should make it easier to assess the relative importance of climate policy on the production relocation of specific sectors. The 'evidence-drivers' framework allows for a mixed qualitative-quantitative assessment. We will apply elements of the 'evidence-drivers' framework to the European iron and steel industry in the case study in Chapter 6.

## 5 Case study – the European steel sector

### 5.1 Introduction

Steel production is a carbon-intensive activity. For the production of one ton of steel in Europe, on average 1.3 tons of CO<sub>2</sub> are emitted to the atmosphere (BCG, 2013). The EU27 iron and steel industry emits about 120 million tons of CO<sub>2</sub> annually (2010-2012; EEA data viewer, November 2014) and is thus responsible for more than 20% of emissions of manufacturing industry and construction in Europe. The energy and carbon intensity of steelmaking decreased considerably in the 1980s and 1990s, when obsolete technologies of steelmaking (e.g., 'Open Heart' furnaces) were abolished, more metal scrap was recycled, and the process of 'casting', i.e., the casting or moulding of liquid steel into certain shapes,



dimensions and weights, became more energy-efficient with the introduction of the continuous-casting process.

Steel is produced in a large number of varieties for a large number of end-uses. Major end-uses are construction, the car industry, mechanical engineering, and metal goods. Steel is an essential input for many renewable energy supply technologies such as (offshore) wind mills and other renewables such as geothermal, hydro, and biomass (BCG, 2013: 36).

Steel is produced by a primary route from iron ore and by a secondary route from ferrous scrap. The major primary route in the EU is the blast furnace converter (BF-BOF) or integrated route that produces steel from iron ore in two integrated steps. In the first step, iron ore (which is an iron oxide) is reduced, i.e., the oxygen is separated from the iron. This is done in a blast furnace (BF) by the gas carbon monoxide (CO) which is generated from the carbon of coal and coke and oxygen (O<sub>2</sub>) from the injected blast. The reduced liquid iron is called 'hot metal'. In the second step, the hot metal is led into a basic oxygen furnace (BOF) or 'converter' where oxygen is injected to remove any unwanted elements and as much carbon as needed to convert the metal into the required steel quality (with a carbon content of typically below 2%). To avoid overheating, coolants are needed in this process. These coolants can be added in the form of scrap, cold pig iron or direct reduced iron. The major secondary route for steelmaking is melting ferrous scrap in an electric arc furnace (EAF).

In the EU27, 59% of crude steel is produced by the primary BF-BOF process and 41% by the secondary EAF process. The BF-BOF process of steelmaking is predominant in northern and northwestern Europe (Germany, France, Poland, the Netherlands and the UK) and the EAF in southern Europe (Spain and Italy) that imports scrap from northern Europe (Neuhoff et al. 2014). The specific greenhouse gas emissions from BF-BOF steel are higher (1.9 tCO<sub>2</sub>/t crude steel) than those of EAF steel (0.46 tCO<sub>2</sub>/t crude steel), but EAF capacity is naturally limited by the availability of scrap and product quality requirements (BCG, 2013). Primary steel production specializes in products with high quality requirements (often flat products), while secondary steel production is better suited for lower added value, bulky (round) products (Mohr et al. 2009).

World crude steel production was 1600 million tonnes (Mt) in 2013. The largest producing countries are China, Japan, the US, India and Russia. China alone produces almost half of global steel production. The largest steel producing company is ArcelorMittal with 6% of global production (Worldsteel, 2014). The fastest growth in investment and steel-producing capacity is in China and the emerging economies (BRICS). Before the economic crisis in 2008, Europe's production level was almost 200 Mt per year. During the crisis production fell by 20% to a level of about 160 Mt (10% of world production) and only now (2014) Europe's industry is showing signs of recovery. European steelmaking offers direct employment to about 350,000 people in 23 EU Member States, and millions of people indirectly (Eurofer, 2014). Its contribution to GDP is 1.4 % (Eurofer, 2014).

Steel is a trade-intensive product and the global steel market is highly competitive. The EU industry's trade intensity with third countries is above 30% (Eurofer 2014). Annual steel

exports in 2013 totaled 38.7 Mt, while imports totaled 30.8 Mt (Worldsteel, 2014). The biggest import sources are Russia, Ukraine, China, Turkey and South Korea (Eurofer, 2014).

The high carbon-intensity of steelmaking and the high trade intensity of the steel product, seem to make the iron and steel sector vulnerable to carbon leakage if carbon emissions of the sector are regulated in the EU but not, or to a lesser extent, in competing regions such as Russia, the Ukraine, or China. The next section of this report discusses the carbon policy context in which the iron and steel industry operates.

## 5.2 The policy context

In 2005, the European Union Emissions Trading Scheme (EU ETS) was introduced in the EU. The EU ETS is a 'cap and trade' system. The volume of emissions that can be emitted each year by the power plants, factories and other companies covered by the system is subject to a cap set at EU level. Within this EU-wide cap, companies receive or buy emission allowances which they can trade if they wish. In the first trading period, 2005-2007, the EU ETS covered only CO<sub>2</sub> emissions from power generators and energy-intensive industrial sectors. Almost all allowances were given to businesses free of charge. The second trading period, 2008-2012, coincided with the first commitment period of the Kyoto protocol. The scope of the scheme was widened in geographical area (with the participation of Iceland, Liechtenstein and Norway) and by the inclusion of nitrous oxide emissions from the production of nitric acid by a number of Member States. The proportion of free allowances fell to 90%, the rest was sold via auctions.


The start of the second trading period in 2008 coincided with the onset of the economic crisis. The economic downturn depressed the production of energy and energy-intensive industries and hence their emissions and their demand for allowances. Together with the relative large supply of credits from CDM and JI, this led to a large and growing surplus of unused allowances and credits which depressed the carbon price throughout the second trading period.

Throughout the first and second trading period, the steel industry was well-endowed with free emissions allowances. In a study commissioned by DG Clima, Ecorys (2013) estimated that for every year under the EU ETS thus far, the allocation of free allowances exceeded the verified emissions in the iron and steel sector. In the second trading period, almost 360 Mt CO<sub>2</sub>-eq. was built up in excess allowances (Ecorys, 2013). If these numbers are correct, the supply of allowances was 60% larger than the actual (verified) emissions.

A study by CEPS and Economisti Associati (2013) more or less confirms this result by means of a detailed analysis of a sample of eight different steel plants in Europe (BF-BOF and EAF). The oversupply (as % of actual emissions) per plant in the second trading period ranged from 12% to 125%.<sup>3</sup> Even when indirect costs due to the effect on electricity prices are taken into account, the EU ETS did not lead to positive costs for BF-BOF steelmaking. It did, however,

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<sup>3</sup> Calculated from Table 21 of CEPS and Economisti Associati (2013).




increase costs for the electricity-intensive EAF plants, where high indirect costs more than offset the value of the surplus of allowances. CEPS and Economisti Associati (2013) conclude that even in the first two trading periods, EU ETS induced costs presented “a significant burden for EAF plants” (2013: 143).

The third trading period, 2013-2020, saw a number of changes in the design of the EU ETS. An EU-wide emissions cap replaced the previous system of national caps, with the aim of reducing the risk of oversupply. Every year the size of the cap is reduced by 1.74% so that in 2020 the emissions covered by the cap will be 21% lower than in 2005. A greater part of allowances is sold instead of given away for free, and for those that are given away for free harmonized allocation rules apply that are based on benchmarks of emissions performance. Some sectors (such as aviation) and gases have been included in the system.

In manufacturing industry the transition to the auctioning of allowances (instead of allocated for free) is taking place gradually. Manufacturing industry received 80% of its allowances free of charge in 2013 but this will decrease annually to 30% in 2020. Allowances not allocated for free will be auctioned. An exception is made for those sectors and sub-sectors which are deemed to be exposed to a significant risk of carbon leakage and are placed on the Carbon Leakage List (CLL) that is updated every five years. The first CLL (covering the years 2013-2014) contains 170 sectors and subsectors, including the sector ‘Manufacture of basic iron and steel and of ferro-alloys’, the ‘casting of iron’, and the ‘casting of light metals’. Installations in these sectors and sub-sectors receive free allowances for the whole 2013-2020 period, based on their historic emissions, up to the benchmark performance level. Installations falling short of the benchmark receive a proportionately lower allocation of free allowances compared to their emissions, and therefore need to reduce their emissions and/or buy more allowances. The second CLL (covering the years 2015-2019) also includes the iron and steel sector. The EU ETS Directive expresses the intention to reach ‘no free allocation’ in 2027, although it is not clear whether this ‘intention’ also applies to the sectors on the CLL list. As of 2013, Member States are, in principle, allowed to adopt financial measures to compensate EITE sectors for the CO<sub>2</sub> costs that are passed on in electricity prices (European Commission, 2009, Article 10a:6).

### 5.3 Option and opinions

The development of the EU ETS post 2020 is not entirely clear yet. In the 2030 framework for climate and energy policy agreement, a market stability reserve is proposed and the annual linear reduction rate of the EU-wide cap is increased from 1.74% to 2.2% as of 2021. The 2013 Green Paper that has the objective to consult stakeholders on the development of the 2030 framework, briefly addresses competitiveness issues. It discusses electricity prices that have increased over the last decade and that are likely to increase further towards 2030. It proposes a number of options to address the negative impacts of energy costs on the competitiveness of the EU economy. They include full implementation of the internal market



legislation, increasing exploitation of indigenous oil and gas resources, both conventional and unconventional in an environmentally safe manner, the further diversification of energy supply routes, an international climate agreement in the context of the Durban Platform, international cooperation in aviation and maritime, and reflection on the continuation of state aid rules that allow Member States to provide compensation for indirect costs to electricity-intensive industries and targeted exemptions from energy related taxes, and the wider use of EU ETS related revenues to assist sectors to innovate.

The European Commission organised a public consultation in 2014 to discuss different options for a system to avoid carbon leakage after 2020. The consultation focused on how many allowances should be dedicated to addressing the risk of carbon leakage post-2020 and what respective roles free allocation and support for industrial innovation should play. The final conclusions of the public consultation are not yet available, but from intermediate reports it appears that there is broad support for more funding for innovation, and that there is a call, especially from industry, to base the allocation of allowances on more recent production volumes, and to take account of indirect cost increases because of increasing electricity prices.<sup>4</sup>

In particular, the European Steel Association EUROFER proposes (Jeekel, 2014):

- “Provide sectors at risk of carbon leakage with 100% free allocation at the level of the most efficient installations, based on achievable benchmarks and no correction factor and continuation of 100% free allowances beyond 2020.
- Provide sectors at risk of carbon leakage with full off-setting of CO<sub>2</sub> cost-pass through in electricity prices in all member states by either financial compensation, free allocation, or re-designing the electricity market in a way that it prevents any carbon price pass through in electricity prices, or a combination of these.
- The repartition of the ETS cap between a manufacturing cap and a power cap shall become flexible to allow full free allocation up to the level of the benchmark to every leakage industry. The remaining part is left for auctioning. In this way there is no longer any need for a correction factor.
- Leakage industries should receive free allocation for their direct emissions up to the level of their benchmarks times the effective production (based on the year n-1); they need however to purchase and surrender additional allowances to cover the emissions emitted beyond the benchmark times the real production level.”

Hence, European Steel asks for the continuation of free allowances for sectors at risk of carbon leakage, compensation for CO<sub>2</sub> cost-pass through in electricity prices, and an output-based allocation system. In the next Chapter, we use a CGE model to examine the effects of this proposal on carbon leakage and the competitiveness of the European steel industry.

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<sup>4</sup> Information on stakeholder meetings on the future of the EU ETS can be found on the webpage: [http://ec.europa.eu/clima/policies/ets/cap/leakage/index\\_en.htm](http://ec.europa.eu/clima/policies/ets/cap/leakage/index_en.htm)

## 6 A CGE model simulation

### 6.1 Introduction

This chapter presents the results of a CGE analysis into feasible scenarios of the evolution of competitiveness and leakage for alternative instrument mixes and alternative levels of global participation in climate change policies. The analysis builds on earlier work in the CECILIA2050 project that developed long-term global scenarios (Zelljadt, 2014; Meyer et al. 2014) and takes account of the policy context and stakeholder opinion that was discussed in Chapter 5. The analysis pays specific attention to investment leakage and long-term effects on the competitiveness of the European steel sector.

### 6.2 Methodology

#### 6.2.1 The model

The applied economic model that is used to carry out the simulations that are described in the section is GDynE, a recursive-dynamic multi-sector, multi-region Computable General Equilibrium (CGE) model of the world economy, including energy and CO<sub>2</sub> emissions (Golub, 2013). The GDynE model is a daughter of the well-know GTAP model of global trade (Hertel, 1997). It is specifically designed to evaluate the economic and trade effects of policies that constrain the emissions of CO<sub>2</sub> in one or more regions of the world. The model takes into account the interactions of decisions of consumers and producers in all markets. These decisions are uniquely determined by (relative) prices. Consumers have preferences over private consumption goods, a composite government good, and savings. Total demand for goods is the sum of final and intermediate demand. Producers maximize profits given a constant returns to scale production technology for all firms. The competitive equilibrium in the model is characterized by market clearance on all markets and by the zero-profit condition for all firms. The substitution between domestically-produced and imported goods is imperfect, following the approach suggested by Armington (1969) to treat goods of different origin as different, non-homogeneous goods. Compared to its comparative-static sister model GTAP-E (Burniaux and Truong, 2002), GDynE has an advanced investment mechanism and accounts for the international mobility of capital. The investment dynamics of GDynE is briefly explained below.

#### 6.2.2 Investment dynamics

The GDynE model accounts for the international mobility of capital. International investments are modelled in a relatively simple way. Investors determine their international portfolio of investments in the equity of firms based on rate of return and relative country risk. If perfect capital mobility was assumed, a change in rate of return on capital in one country would instantaneously lead to an international reallocation of capital such that the rates of return would be equalized. Because this would lead to unrealistic high volatilities in

the level of international investment and the prices of capital goods, the investment theory of GDynE follows a lagged adjustment approach that assumes the equality of rate of return across countries only in the long run (Ianchovichina and Mc Dougall, 2001).

What if a country implements GHG emission reduction policies? Because of the basic complementarity between capital and emissions, a GHG emission reduction policy will reduce the return on capital and investors will reevaluate and adjust their investment portfolios, relocating capital from the policy country to countries where the rates of return are expected to be higher. This adjustment gives rise to what is called 'investment leakage' (Golub, 2013).

### 6.2.3 Innovations

The standard GDynE model and most other CGE models assume equivalency between emissions trading and a carbon tax in the sense that they invoke equivalent behavior from the regulated firms. In particular, they assume the equivalency irrespective of whether emissions allowances are allocated for free or whether they must be purchased. In the standard 'grand-fathering' emissions trading system, firms assign the same value to allowances that they purchased and that they were given for free. The EU ETS does not, however, meet the characteristics of a 'grand-fathering' emissions trading system in every respect. For example, emissions allowances are withdrawn if an installation permanently ceases operation (EC, 2003: Article 10a.19). Free allocation is also based on 'benchmarking' provisions (EC, 2003: Article 10a.1) that have the objective to give firms incentives to reduce their GHG intensity. Firms may also assume that the reference production volumes that appear in the formula from which the free allocation per installation is calculated are updated in the future and will not remain the average of the 2005-2007 period for ever.<sup>5</sup> From a theoretical perspective the EU ETS seems to develop into the direction of an 'output-based' emissions trading system where the mode of allocation (free or for money) does matter and the free allowances can be regarded as an output subsidy to the regulated industry (see, for example, Fischer, C., 2001; Kuik and Mulder, 2004). In the current model, the EU ETS is represented as an output-based emissions trading system for those sectors that receive free allowances. The output 'subsidy' is equal to the direct and indirect costs of the EU ETS (the extra costs of allowances and electricity). Despite this 'subsidy' firms still have an incentive to optimally reduce their GHG intensity of production. In theory, the output-based system is equivalent to a *combination* of an efficient cap-and-trade system and a production subsidy. To reach the same *national* level of emission reduction, prices of emissions permits, the level of abatement, and the output of goods are higher than under a standard cap-and-trade system (Gielen et al., 2002).

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<sup>5</sup> The formula is: benchmark GHG-intensity per unit of product x average production volume in the period 2005-2007.



### 6.3 Data and assumptions

Economic, energy and emissions data from the GTAP version 8 database were aggregated into 23 regions, 10 sectors/commodities, and 3 primary factors of production (land, labour and capital). In the regional aggregation, we followed Antimiani et al. (2014). The regions include 7 developed regions (Canada, European Union, Former Soviet Union, Japan, Norway, United States, and the Rest of OECD), and 16 developing regions (Brazil, China, India, Indonesia, Korea, Mexico, Asian Energy Exporters, African Energy Exporters, American Energy Exporters, Pakistan/Philippines/Thailand, Rest of Asia, Morocco/Tunesia, Rest of Africa, Rest of America, Rest of Europe, and Vietnam). For the sectoral aggregation, we included the energy sectors (coal, crude oil, natural gas, oil products, and electricity), two energy-intensive manufacturing sectors (iron and steel and other energy-intensive and trade-exposed (EITE) sectors), other manufacturing, services, and agriculture & food processing.

In CGE simulations of carbon leakage, a number of elasticities play an important role. In economics, an *elasticity* measures the percentage change in the dependent variable due to a one-percent change in some independent variable. For example, the elasticity of demand of a good ( $y$ ) is defined as the percentage change in demand for a good due to a one-percent change in its market price ( $p$ ). In formula:

$$\varepsilon_{y,p} = \frac{\frac{dy}{y}}{\frac{dp}{p}} = \frac{dy}{dp} \cdot \frac{p}{y}$$

In CGE analyses of carbon leakage, a number of elasticities are very important. They include the supply elasticities of fossil fuels, trade elasticities that measure the change in imports when the relative price between imports and domestic production changes (the so-called ‘Armington’ elasticities), and the substitution elasticities between energy and capital in the production functions of firms. We used the standard GDyn values for those elasticities, except for the energy-substitution parameters for which we followed Antimiani et al. (2014), who base their slightly lower values on recent empirical evidence.<sup>6</sup> It should be noted that both Antimiani et al. (2014) and we apply these values for calculating baseline emissions, but increase the value of the elasticity of substitution of energy and capital for scenarios with carbon abatement policies to reflect the effect of these policies on the direction of technological development. This is discussed below.

### 6.4 Simulation design

We modelled four scenarios that were developed in the CECILIA2050 project by the work of Zelljadt (2014) in Deliverable 5.1 and Meyer et al. (2014) in Deliverable 3.2. The Baseline scenario is a scenario without active climate policy globally. It is described in Meyer et al.

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<sup>6</sup> The elasticities are ...



(2014) and follows IEA Energy Technology Perspectives' 6 degrees Celcius (ETP 6 DC) scenario. In fact, our baseline emissions turn out a little lower than those of Meyer et al. and follow more closely those of Antimiani et al. (2014). For the present report this is of little interest because we will not use the baseline in the simulations. The Middle of the Road scenario is a scenario that follows the IEA ETP 4 DC scenario. All countries have carbon abatement policies implemented, but these policies are not very ambitious and they do not converge internationally, i.e. they are not coordinated internationally (Zelljadt, 2014). In Meyer et al. (2014), EU countries pursue the 2DC target within the global Middle of the Road scenario. For our analysis, we will distinguish a Middle of the Road (MR) scenario and a Middle of the Road Plus (MR+) scenario, in which the EU pursues the 4DC target scenario in the former and the 2DC targets in the latter. Hence, the Middle of the Road scenario of Meyer et al. (2014) is identical to our Middle of the Road Plus scenario. Finally, the Global Cooperation (GC) scenario follows the IEA ETP 2DC scenario. Policies are ambitious and converge to one global emissions trading scheme. The emission reduction target for the EU is equal to its target in the MR+ scenario, but the EU can now take advantage of international emissions trading.

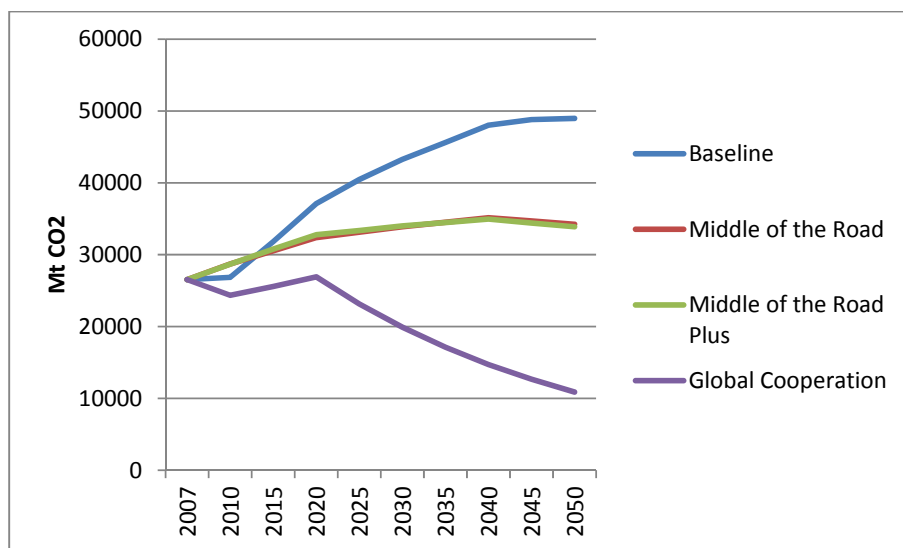


Figure 2 Global CO<sub>2</sub> emission paths (Mt CO<sub>2</sub>) in four scenarios

It is assumed that the substitution possibilities between energy and capital are increased by technological progress. It is also assumed that technological progress in this area increases from the Baseline to the MR scenario and is largest in the GC scenario. Quantitatively we made the assumption that the elasticity is 50% higher in the Middle of the Road scenario and 100% higher in the Global Cooperation scenario. That is, in the Middle of the Road scenario it is one-and-a-half times easier to substitute capital for energy and in the Global Cooperation scenario it is two times easier.<sup>7</sup>

<sup>7</sup> These differences in elasticities explain why emissions in 2010 are not exactly equal in all scenarios in Figure 2.

For our policy analysis, we make different assumptions about the free allocation of allowances to the energy-intensive and trade exposed sectors in the EU. We assume that free allocation has *the effect* of an output-based system of allocation. We distinguish between ‘no free allocation’, ‘free allocation up to 2027’ which we shall call the ‘base’ variant, and ‘free allocation up to 2050’, which we shall call the ‘alternative’ variant. This results in the following policy simulations:

- Middle of the Road Plus scenario, no free allocation (MR+).
- Middle of the Road Plus scenario, free allocation up to 2027 (base) (MR+bas).
- Middle of the Road Plus scenario, free allocation up to 2050 (alternative) (MR+alt).
- Global Cooperation scenario, no free allocation (GC).

We compare these simulations against the MR scenario without carbon taxes. The GC scenario has no free allocation of allowances because we assume that all countries take on emissions targets and there can be no carbon leakage per definition. The motivation for allocating allowances for free to certain industries, i.e. the ‘fear of carbon leakage’, is not relevant in this case.

We first examine, as a hypothetical scenario, the MR+ scenario without free allocation. In this scenario, the EU has as stricter climate target than the countries in the rest of the world. The requirement of EU firms to purchase carbon allowances causes their production costs to increase vis-à-vis their competitors abroad and this causes carbon leakage. This may cause carbon leakage and industrial relocation. Following a method first suggested by Burniaux (2001) and elaborated by Golub (2013), we decompose carbon leakage into its constituent ‘energy market’, ‘terms-of-trade’, and ‘international investment’ channels. This decomposition gives insight into the share and the evolution of the international investment channel of carbon leakage.

We then assess the evaluation of the competitiveness of the European iron and steel sector and carbon leakage in the different scenarios. In Deliverable 2.8 (Kuik et al., 2013), it was argued that competitiveness is best understood as an ability. As ability itself is difficult to measure, indicators of competitiveness are determinants or consequences of this ability. In this report we use the carbon price as the determinant-indicator. We use ‘volume of exports’, ‘relative trade balance’, and ‘revealed comparative advantage’ as consequence-indicators. Recall the definitions of relative trade balance (RTB) and revealed comparative advantage (RCA) from Deliverable 2.8. The relative trade balance (RTB) for sector  $i$  measures net exports of a country (exports  $X$  minus imports  $M$ ) as share of the total trade of that country (exports  $X$  plus imports  $M$ ) in a certain period. In formula:

$$RTB_i = \frac{(X_i - M_i)}{(X_i + M_i)}$$

Revealed comparative advantage (RCA) of sector  $i$  of country  $j$  measures its relative exports (exports  $X_i$  as a share of total exports  $\sum X_i$ ) against the relative exports of sector  $i$  of a reference group of competitor countries  $k$ . In formula:

$$RCA_{j,i} = \frac{\frac{X_{j,i}}{\sum X_{j,i}}}{\frac{X_{k,i}}{\sum X_{k,i}}}$$

## 6.5 Assessment of policy options

### 6.5.1 Middle of the Road (MR)

In the MR scenario, global CO<sub>2</sub> emissions increase from 2.8 Gt in 2010 to 3.4 Gt in 2050, with a peak of 3.5 Gt in 2040. EU emissions decrease from 0.4 GT in 2010 to 0.2 Gt in 2050. In this scenario, the competitiveness of the EU iron and steel industry is maintained over the simulation horizon, with an initial increase in competitiveness up to 2030 as compared to the current level of competitiveness (Note: RTB is Relative Trade Balance: RCA is Revealed Comparative Advantage

Figure 3).



Note: RTB is Relative Trade Balance: RCA is Revealed Comparative Advantage

Figure 3 Indicators of competitiveness of the EU's steel industry in the Middle of the Road scenario

### 6.5.2 Middle of the Road Plus (MR+)

In the MR+ scenario, without free allocation scenario, CO<sub>2</sub> emissions in the EU are capped and are annually reduced to meet the EU's 2DC target. EU emissions decrease from 4 Gt in

2010 to 1.5 Gt in 2050.<sup>8</sup> The carbon price in the EU increases from current levels of around € 5 to € 223 per tonne of CO<sub>2</sub> in 2050.<sup>9</sup> The CO<sub>2</sub> abatement policy causes carbon leakage. The rate of carbon leakage increases from 14% in 2015 to 44% in 2050. This means that of total CO<sub>2</sub> abatement in the EU in 2050, 44% is offset by increased emissions abroad. In our simulation, the largest increases of emissions (in absolute terms) are in China, Energy Exporting countries of Asia (Middle East and Malaysia), and India.

We decomposed this carbon leakage into energy, terms-of-trade and international investment channel effects.<sup>10</sup> Figure 4 suggests that in this scenario initially the energy market channel dominates carbon leakage. However, over time the terms-of-trade effect and especially the international investment channel gain importance. In 2050, almost 60% of carbon leakage is expected to pass through the international investment channel.

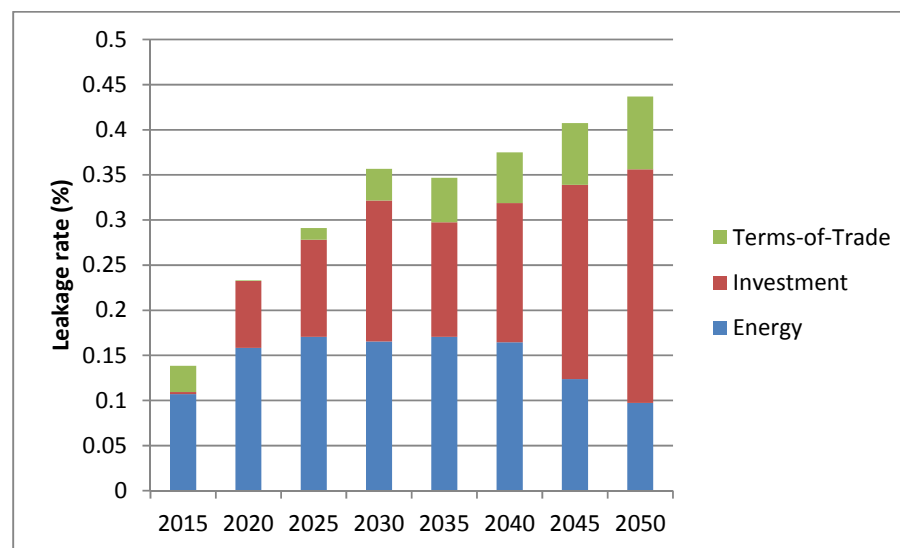


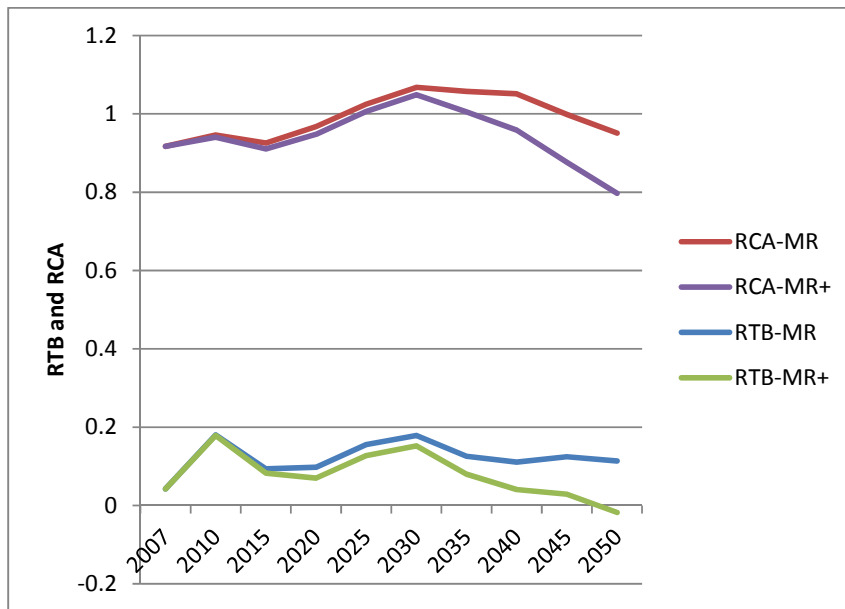
Figure 4 Channels of carbon leakage in the Middle of the Road Plus scenario

In the MR+ scenario, the competitiveness of the EU iron and steel industry is not much affected until 2030, but decreases after 2030 as compared to the MR scenario. In 2050 the Relative Trade Balance for iron and steel turns negative, indicating that the EU turns from being a net exporter of iron and steel into a net importer. The indicator of Revealed Comparative Advantage drops to 0.8 at the end of the simulation horizon, pointing to a (growing) relative disadvantage for European steelmaking (Figure 5).

<sup>8</sup> This target is equal to the EU 'Middle of the Road' target in Deliverable 3.2 (Bernd et al. 2014).

<sup>9</sup> The CO<sub>2</sub> price is almost equal to the EU ETS price of € 230 in Deliverable 3.2 (Bernd et al. 2014).

<sup>10</sup> This is done by running two intermediate simulations as well as the original simulation. In the original simulation all channels of carbon leakage are simulated. In the first intermediate simulation the world market prices of fossil fuels are held constant; in the second intermediate simulation the world market prices of fossil fuels are held constant and international capital mobility is disallowed. The difference between the original simulation and the first intermediate simulation gives the 'energy' channel. The difference between the first and the second intermediate simulation gives the 'investment' channel. The third intermediate simulation gives the 'terms-of-trade' channel.



Note: RTB is Relative Trade Balance: RCA is Revealed Comparative Advantage

Figure 5 Indicators of competitiveness of the EU's steel industry in the Middle of the Road Plus scenario

### 6.5.3 Middle of the Road Plus (MR+bas and MR+alt)

We now describe two scenarios in which the competitiveness of the EU energy-intensive and trade exposed industry is protected by granting them free allowances. In the first scenario, free allowances are granted up to 2027 (MR+bas) and in the second scenario they are granted for the entire time period up to 2050 (MR+alt). Free allocation of allowances has effects on the carbon price, carbon leakage and competitiveness. We discuss these effects in turn. We compare the effects with the MR+ scenario.

The direct and indirect costs of the CO<sub>2</sub> policy are between 0.3% and 1.9% of total output in the steel industry and between 0.2% and 1.0% in the other EITE sector. At the start of the simulation, the costs are dominated by increased electricity costs, at the end of the period the carbon allowance cost and the increased electricity costs are almost equal in size. We assume in the present scenarios that the direct and indirect costs of the steel industry and the other EITE sector are compensated by free allowances and a compensation for the increased electricity costs.

Free allocation of carbon allowances and compensation for electricity price rises, increases the carbon price. This is a standard theoretical result for output-based allocation of allowances. The implicit subsidy to CO<sub>2</sub>-intensive production counters the shift of the composition of the economy in the direction of less CO<sub>2</sub>-intensive sectors. Hence, to meet the emissions target, the technique effect (CO<sub>2</sub>-intensity per unit of output) should be decreased. Therefore the incentive to lower CO<sub>2</sub>-intensity, the CO<sub>2</sub> price, should be increased. Figure 6 shows that the difference between the carbon prices between the MR+

and the MR+bas is very limited, but that the difference increases if free allowances are granted up to 2050 (MR+alt). In 2050 the carbon price in MR+bas is 10% higher than in the scenario without free allocation (MR+).

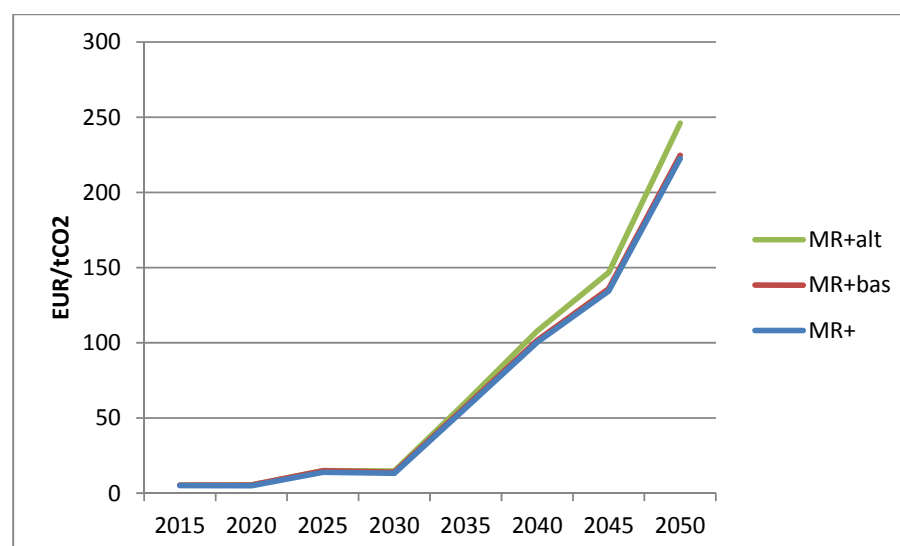


Figure 6 The carbon price under three different allowance allocation schemes

Our simulations suggest that output-based allocation of free allowances reduces carbon leakage, but does not prevent it (Figure 7). With free allowances and compensation for electricity price increases, carbon leakage in 2015 is 7% against 14% in the scenario without free allocation. If free allocation and compensation are maintained during the entire period (MR+alt), carbon leakage at the end of the period is 33% against 44% in the scenario without free allocation (MR+).

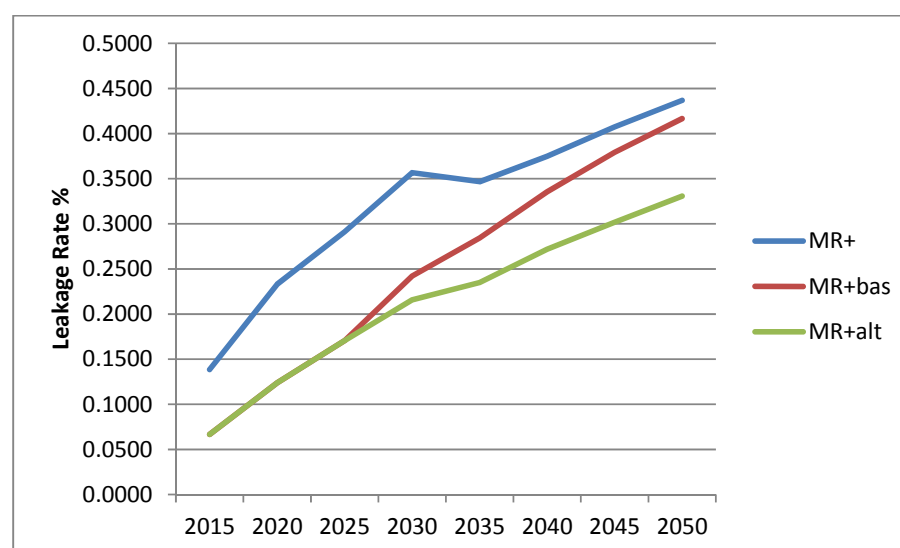
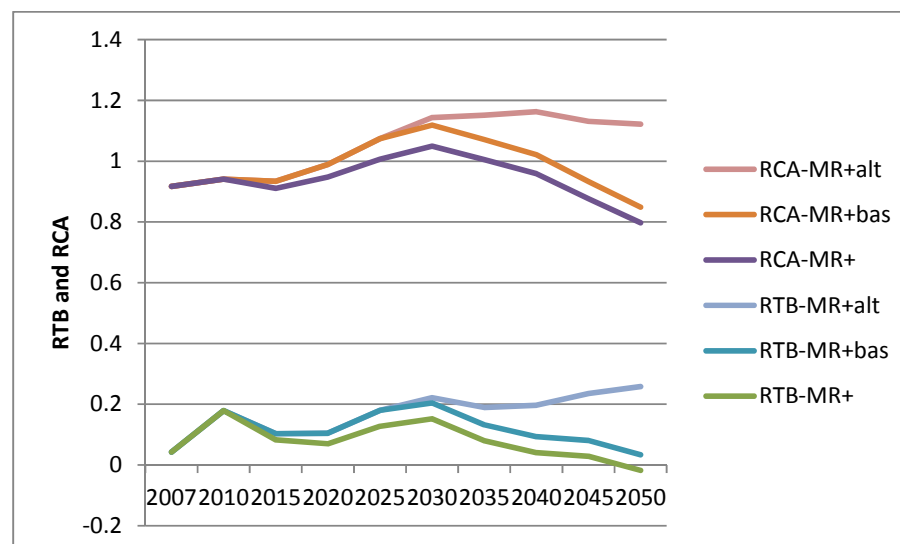


Figure 7 Carbon leakage under three different allowance allocation schemes

The competitiveness of the energy-intensive sectors increases under the free allocation alternatives. Figure 8 suggests that the competitiveness of the EU iron and steel sector and the other EITE sector increases somewhat up to 2030 and then decreases under the MR+bas scenario (when allowances have to be bought after 2027) and remains stable and positive in the MR+alt scenario (when allowances remain free of charge).



Note: RTB is Relative Trade Balance: RCA is Revealed Comparative Advantage

Figure 8 Competitiveness under three different allowance allocation schemes

Output-based allocation of free allowances (MR+alt) safeguards the competitiveness of the European EITE sectors, but carbon leakage is not avoided. To understand this seemingly contradictory result, we need a deep decomposition of carbon leakage. We focus on the effects of the EU policies in China at the end of the simulation period (see Table 4). In the MR+ scenario, CO<sub>2</sub> emissions in China would be 115 Mt higher than in the baseline (MR) scenario in 2050. About one-quarter of this increase (30 Mt) is due to the fall of the world market price of fossil fuels. Because of the direct and indirect carbon costs for EU producers, the competitiveness of the Chinese EITE sectors will increase. Without international capital mobility, Chinese EITE sectors would emit 9 Mt more than in the baseline, this is a pure terms-of-trade effect. With the help of international investment, output (and export) of the Chinese EITE sectors is increased further, which pushes up additional emissions to 20 Mt. The remainder of the emissions increase (115 Mt – 30 Mt – 20 Mt = 65 Mt) is due to an increase in emissions of non-EITE sectors, especially electricity generation. This is partly due to an increase in intermediate demand of the EITE sectors (for, for example, electricity), but also due to the relative growth of the economy which increases total demand for all goods and services.

In the MR+alt scenario, CO<sub>2</sub> emissions in China are 28 Mt lower than in the MR+ scenario (115 Mt – 87 Mt) (See Table 4). Half of this difference is due to lower emissions from the Chinese EITE sectors (–13 Mt). In this scenario, the pure terms-of-trade effect for China is negative (–2Mt), and the remaining leakage is completely due to the energy and international investment channels. The output-based free allocation of allowances cannot avoid the

decrease in world market prices of fossil fuels, nor can it avoid the overall loss of return on capital in the EU that gives incentives to investors all over the world to adjust their investment portfolios towards markets with relatively higher returns.

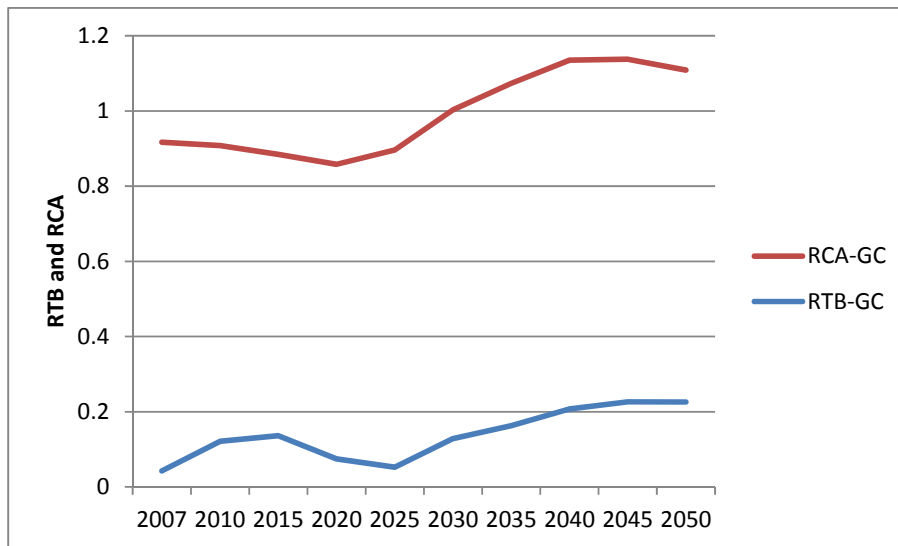
**Table 4 Simulated changes in emissions in China in 2050 due to two alternative EU CO<sub>2</sub> abatement policies**

	MR+	MR+alt
Change in emissions with all channels	+115	+87
Change in emissions without energy market channel	+85	+56
Change in emissions without energy market and international investment channels	+19	+1
Change in emissions EITE sectors with all channels	+20	+7
Change in emissions EITE sector without energy market and international investment channels	+9	-2

#### 6.5.4 Global Cooperation (GC)

Global cooperation to reach the 2DC target is the optimal climate policy. In the Global Cooperation scenario we assume that starting in 2020 there is an international climate agreement with binding targets for all countries and one global emissions trading scheme. The global CO<sub>2</sub> price starts at € 40 per tonne CO<sub>2</sub> and increases rapidly with more than 10% per year to a price of € 615 in 2050. Because all countries have binding emissions targets there is no carbon leakage by definition. Although there are no free allowances for energy-intensive and trade-exposed sectors in this scenario, the competitiveness of the EU iron and steel industry is maintained in the short to medium term and even increases after 2025 (Figure 9).






Note: RTB is Relative Trade Balance: RCA is Revealed Comparative Advantage

Figure 9 Competitiveness under the Global Cooperation scenario

## 7 Conclusions

The risk of carbon leakage and the fear of loss of competitiveness are disincentives for ambitious climate change policies. This study examined the determinants of carbon leakage and competitiveness in the long run, with a focus on the European steel industry. According to the Pollution Haven effect, a tightening up of pollution regulation in one country or region will, on the margin, affect plant location decisions and trade flows in the direction of regions with weak environmental regulations. However, these tendencies may be counteracted by technological and organizational innovations that may be induced by the stringent policies (Porter Hypothesis). In the long-run, the location of industry is affected by FDI flows. The nature of these flows has long been a bit of a puzzle in standard neo-classical theory. On the basis of theoretical developments in trade theory ('new trade theory') and contract theory, important innovations have been made in the theory of the multinational enterprise and FDI. On the basis of this new theory, an empirical study suggested that the relationship between environmental stringency of the host country and inward FDI can be depicted by an inverted U curve. A decrease in environmental stringency in the host country will have a positive impact on the amount of FDI up to a limit or threshold after which the impact will become negative. The idea is that if environmental stringency is too low, investors may interpret this as a signal of poor regulatory quality that poses a risk for their investments. Hence, the relationship between environmental stringency and FDI would be non-linear.

One industry that is at risk of carbon leakage in the EU is the steel industry. The high carbon-intensity of steelmaking and the high trade intensity of the steel product, make the steel sector vulnerable to carbon leakage if carbon emissions of the sector are regulated in the EU but not, or to a lesser extent, in competing regions such as Russia, the Ukraine, or China. We




used a CGE model to develop feasible scenarios of the evolution of competitiveness of the steel industry and carbon leakage for alternative instrument mixes and alternative levels of global participation in climate change policies. It can be concluded from the analysis that, without any safeguards to the industry, and in the event of moderate climate ambitions in the rest of the world, an ambitious climate policy in Europe could lead to a significant loss of competitiveness of the steel sector and a high and increasing rate of carbon leakage. An increasing part of the carbon leakage is due to changes in international investment patterns. This so-called ‘investment leakage’ would be responsible for 60% of carbon leakage in 2050.

Granting free carbon allowances to all EITE sectors in an *output-based* fashion after 2020 and compensating them for increased electricity costs, would, according to the analysis, mitigate fears of loss of competitiveness and reduce, but not eliminate, carbon leakage.


Fears of loss of competitiveness and risk of carbon leakage would also disappear if countries were to agree on coordinated ambitious action to tackle climate change. In such a Global Coordination scenario there would be no carbon leakage per definition and our simulations suggest that the competitiveness of the European steel industry would increase in the long term.

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